

Taxonomic Study on the Wild Species of Genus *Solanum* L in the Southern Western Ghats of Tamil Nadu

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Abstract

An excursion flora of *Solanum* (Solanaceae), distributed in Southern Western Ghats ecoregions of Tamil Nadu. The work illustrated to study of complete morphological features of each species, distribution, nomenclature, synonyms, vernacular name, common name, flowering season, Geographical locations, Ecological status, GPS co-ordinate, elevation, habitat, ethnomedicinal uses, formulations and the taxonomic relationships between the studied species is represented by the cluster analysis. The Morphological characters indicated highly significant role in the identification of the species. Based on the detailed survey, two species was native species and remaining three species were invasive plants. The morphological variations measured by Eluclidean distance process and phonogram were constructed. The phenogram showed that the studied species of genus *Solanum* can simply be divided into two groups that are *Melongena* and *Solanum*. The phylogram was represented by using parsimony analysis of the morphological data. The phylogram showed that most of the species are distributed all over the study area. Therefore the goal of the present study was to identify distinctive morphological feature on both of Phylogram, and Phenogram. The results was represented showed great similarity between *S.virgianianum* and *S. incanum* suggesting that the two species can be considered as one species with two subspecies or varieties.

Keywords: *Solanum*; Taxonomic Relationships; Cluster Analysis

Introduction

Solanum L. constitutes large and diversified cosmopolitan genus and comprises about 1500 species, Solanaceae comprises of 90 genera with approximately 3000 species [1]. An egg plants are an economically important food crop, distributed in throughout temperate and tropical regions, with more than 2,000,000 hectares dedicated annually their cultivation (2008 data: <http://faostat.fao.org>) *Solanum* species are often confused as a

result of diversity in their gross morphology and eco - geographical distribution [2,3]. Particularly Southeast Asia and India, thousands of local landraces and heirloom cultivars exist and these exhibit a wide range of variability in morphology, flavour and pathogen resistances. To conserve landrace diversity, large - scale efforts to collect and maintain germplasm of wild relatives and landraces are underway, currently encompassing more than 15,000 collections in 99 institutions worldwide for landraces alone (wiews; [http:// apps3.fao.org/wiews](http://apps3.fao.org/wiews)) the present

study a total of 5 species of *Solanum* were recorded in southern western ghats ecoregions of tamil nadu. Most of the species were used by the inhabitants in one way or the other. Among these, *S. incanum* and *S. virginianum* has drawn special attention of the world for its Solasodine, Solamargine content, an alkaloidal steroid sapogenin which may be used as starting materials, intermediate in the manufacture of steroid hormones [4].

The current study is aimed to presents the numerical taxonomic analysis of genus *Solanum*. The family Solanaceae plants are widely spread in south India [5]. In this Book "Flora of presidency of Madras" has described 39 species coming under genera the medicinal and economic value of egg plants is found in the Sanskrit's literature [6-8,2]. Out of five, two species has been domesticated vegetables i.e., *Solanum americanum* Mill, and *Solanum torvum* Sw., and three species has been Cultivated for their medicinal values i.e., *Solanum incanum* L. *Solanum virginianum*.L., and *Solanum trilabatum* L., The Genus *Solanum* contains many species of economic potential values for both edible and pharmaceutical importance [9].

Materials and Methods

Description of Study Area

The present study was carried out on five wild *Solanum* species were collected. During the intensive floristic survey conducting from July 2013 to September 2015. Species collected from different southern western ghat ecoregions of Tamil Nadu state, the WGs study area running on the Nilgiri plateau on southwards at an until terminate at Cape Comorin. The tract is situated between $11^{\circ} 30' - 19^{\circ} 30' N$ and $76^{\circ} 29' - 76^{\circ} 36' E$ to $8^{\circ} 03' - 8^{\circ} 35' N$ and $77^{\circ} 15' - 77^{\circ} 36' E$. with the total taluka Area

27,069km², Ecologically Sensitive Areas (ESA) 6,914 and Total Villages with ESA 135. The WG of Tamil Nadu is divided into five ecoregions [1]. These are (i) Nilgiri biosphere reserve (ii) Anamalai, (iii) Palani range (iv) Varushanad - Andipatty and (v) Agasthyamalai biosphere reserve and extend ten districts of Tamil Nadu in the sense of Ecologically Sensitive Areas (ESA): Viz., Nilgiris, Coimbatore, Tiruppur, Erode, Dindugal, Madurai, Theni, Viruthunagar, Tirunelveli and Kanniyakumari. The collected specimens were mounted into herbarium specimens following method [2].

Identification and Authentication of Plant Materials

Floristically the ecoregions of Western Ghats in Tamil Nadu is one of the richest biogeography areas in the country and harbours as many as 4000 - 4600 species of flowering plants of which 56 genera and 2100 species are endemic and threatened due to habitat pressures and number of endangered or rare plant species their type of ecoregions. The plant species were initially identified and got specimen accession number with reference to and herbarium voucher specimen was deposited at Department of Botany, Annamalai University, Annamalai Nagar, Tamil Nadu and Checking with taxonomic literature [10,5]. Further, identified and authenticated By Botanical Survey of India (BSI), Southern Regional Centre and Coimbatore. (BSI/SRC/5/23/2015/Tech. dated on July 7th 2015). The present investigation is the outcome of several field trips carried out in Southern Western Ghats ecoregions with several relevant information was also documented particularly on their habit, characteristic occurrence and local utilization during the years 2013 - 2015.

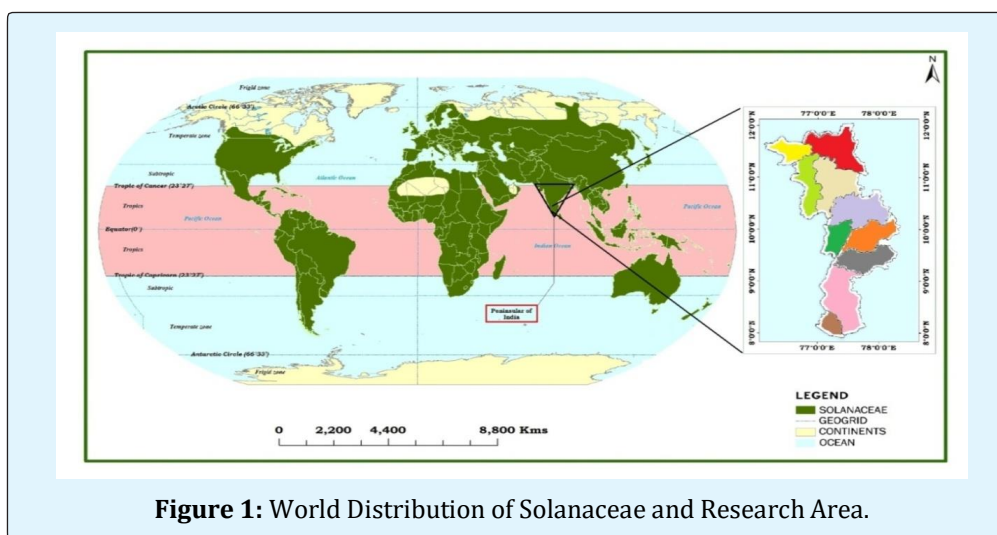


Figure 1: World Distribution of Solanaceae and Research Area.

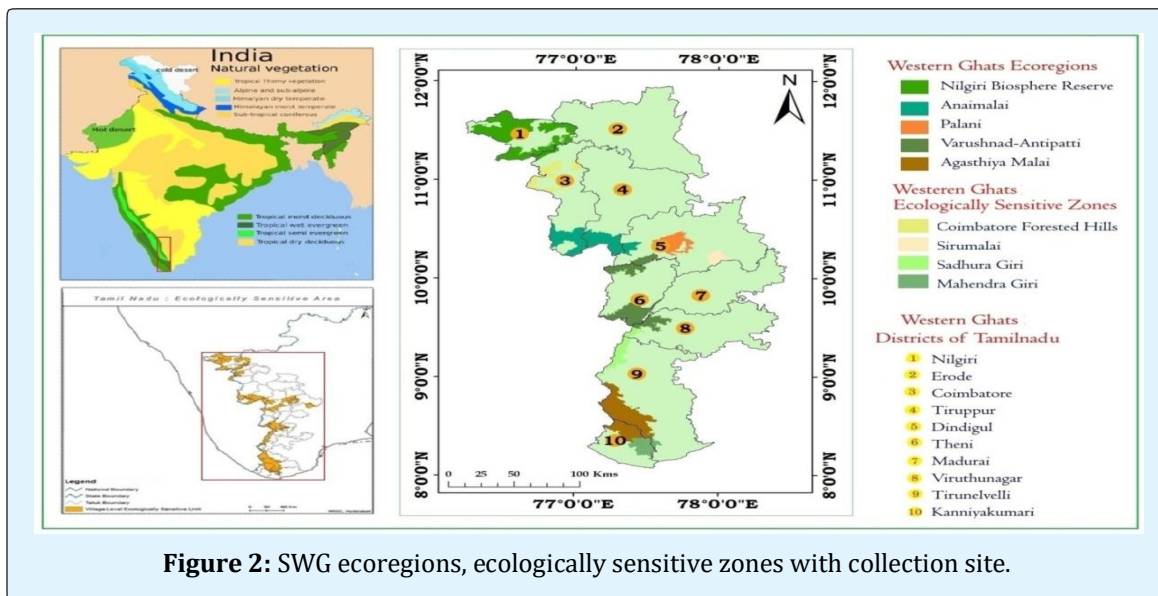


Figure 2: SWG ecoregions, ecologically sensitive zones with collection site.

The present study was carried out on five wild *Solanum* species from different ecoregions found in southern Western Ghats of Tamilnadu as well as information from the literatures. Nomenclature of all five species was updated according to the two major online websites (www.tropicos.org and www.theplantlist.org). The Herbarium vouchers and fresh materials subjected to detailed studies of the variations in several morphological parameters observations were made using a dissecting microscope on morphological characters, such as the variation in size, shape, hairiness and colour in the plants organs Eg, leaves, flowers, fruits and seed etc.

Forty one morphological characters were recorded comparatively for the studied taxa were given in characters and character states were determined through examination of both fresh and herbarium specimens were aided as multistate characters. The data matrix was subjected to cluster analysis using UPGMA (Unweight Pair Group Method with Arithmetic Mean) Phylogram was created to clear the inferred evolutionary relationships among the species. The five species under *Solanum* genera

of Solanaceae morpho-metric analysis have been made with special reference to taxonomical, morphological characters. Morphological variation between the studied species based on squared Euclidean distance was presented in Table No.5. All the analysis was carried out using the program past (version 2.17c) (Table1) [11].

Rank	Countries	Productions (in tons)
1	China	28,433,500
2	India	13,444,000
3	Egypt	1,246,707
4	Turkey	826,941
5	Iran	733,350
6	Indonesia	545,646
7	Iraq	510,918
8	Japan	312,200
9	Italy	302,673
10	Philippines	219,911

Table 1: Worldwide Eggplants production countries (2013).

S.no	Scientific Name With Accession Number	Global Occurrence (GBIF, 2017)		Gene bank holding (AVGRIS,2017, GENESYS, 2017)			
		No. of Records	Cluster of Occurrences	Global numbers of accessions	World Veg number of accessions	% World Veg of Global	Largest collections
1	<i>Solanum torvum</i> . Sw, Acc.No. 290	7,379	L. America, W. Africa, SE Asia	132	112	85	World Veg
2	<i>Solanum incanum</i> . LAcc.No. 242	1,122	Africa	167	5	3	University of Nijmegen

3	<i>Solanum virginianum</i> . L Acc.No. 243	633	SE Asia	31	3	10	Millennium Seed bank
4	<i>Solanum americanum</i> . Mill Acc.No. 244	342	SE Asia	18	3	15	World Veg
5	<i>Solanum trilobatum</i> . L Acc.No.245	257	SE Asia	14	10	71	World Veg

Table 2: World occurrences of some taxa of *Solanum*.

S.no	Plants name with Accession No.	Synonyms, Vernacular Name & Common Name	Ecoregions, Agronomical & Ecological Status	Geographical locations, GPS Coordinate & Elevations	Habit, Habitat & Collection periods	Parts used, formulation & ethno medicinal uses
1	<i>Solanum torvum</i> . SwAcc.No. 290	<i>Solanum ferugineum</i> Jacq. <i>Solanum mayanum</i> Lundell.C Princkly nightshade	Nilgiri Biosphere Reserve, Cultivated, Common	Gudalur, 11° 57'95.99" N 76° 58'19.59" E (MSL - 1,875m)	Shrub, Wild/ Cultivated, Farm/ kitchen garden, July - September	Leaves & Fruits/Fruits powder paste used stomach- ache, colic, headache, painful menstruation and liver pain
2	<i>Solanum incanum</i> . L Acc.No. 242	<i>Solanum panduriforme</i> E. Mey <i>Solanum bojeri</i> Dunal.V. Mullakathirikkai C. Indian nightshade	Anaimalai range, Wild, Rare	Valparai 10° 19'24.92" N 76° 57'3.61" E (MSL - 1,055m)	Herb, Wild, Roadside/waste land August - October	Roots, Leaves and Fruits / The paste of fruits powder is used as vermifuge for Ascaris.
3	<i>Solanum virginianum</i> . L Acc.No. 243	<i>Solanum surratense</i> . Burmf <i>Solanum xanthocaroum</i> . Schr V.Kandakathirikkai C. Yellow - berried nightshade	Palani range, Wild, Rare	Kodaikanal, 10° 14'17.21" N 77° 29'21.05" E (MSL - 2,079m)	Herb, Wild, Roadside May- August	Leaves & Fruits/ Seed soaked in water and used to reduced sperm count, seed smoke used for Tooth ache remedy
4	<i>Solanum americanum</i> . Mill Acc.No. 244	<i>Solanum adventitium</i> . Polger <i>Solanum nigrum</i> . var.nodiflorum (Jacq.)V. Ananthakkali C. Black night shade	Varushnad - Antipatty Range Weeds - Rare	Mega malai ,9° 44'11.26" N 77° 25'21.29" E (MSL - 1,404m)	Herb, Weedy plant, Farm land, cultivated land June - September	Fruits & Leaves/ Leaf Juice used Gastrointestinal ailments
5	<i>Solanum trilobatum</i> . L Acc.No.24 5	<i>Solanum canaranum</i> Miq. <i>Solanum fuscum</i> B.Heyue.ex.wall.V.Tuduvalai .Thai nightshade	Agasthyamala irange, Wild - Common	Kalakadu, 8° 30'54.60" N 77° 33'2.04" E (MSL - 122m)	Climber, Wild, Above the fence July - September	Leaves/ Leaf Juice used pulmonary ailments and cough medicine

Table 3: Collection details of *Solanum* species from Natural Populations of WGEs of Tamil Nadu.

S.no	Characters	Taxa				
		S.torvum	S.incanum	S.virginianm	S.americanm	S.trilopatum
1	Habit: Herb 1/Shrub 2/	2	2	2	1	1
2	Plant height (cm): Less than 1 m 1/1 m or more 2	2	2	1	1	2
3	Stem surface: Glabrous 1/Pubescent 2/Villous 3/Stellate-pubescent 4	4	4	4	1	1
4	Type of stem: Herbaceous 1/Woody 2/ Slender Shrub	2	2	2	1	3
5	Stem Colour: Green 1/Grey-green 2	2	2	1	1	1
6	Leaves armed or not: Unarmed 1/Armed 2	2	2	2	1	2
7	Leaves: Mostly unequal-paired 1/Not so 2	2	2	2	2	2
8	Leaves: Coriaceous 1/Not so 2	2	2	2	1	2
9	Leaf outline: Ovate 1/Elliptic 2/Obovate 3/Oblong 4	1	1	1	1	1
10	Leaf apex: Acuminate 1/Acute 2/Obtuse 3	2	2	1	2	3
11	Leaf margin: Entire 1/Dentate 2/Undulate 3/Lobbed	1	3	4	1	3

	4					
12	Leaf base: Obtuse 1/Cuneate2/Subcordate 3/Oblique 4	3	4	3	1	1
13	Leaf adaxial surface: Glabrous1/Sparsely pubescent 2/Villous3/Stellate-tomentose 4/ Sellate 5	4	4	4	2	5
14	Leaf abaxial surface: Glabrous 1/Sparsely pubescent 2/Villous 3/Stellate-tomentose 4	4	4	4	2	1
15	Leaf length: Up to 5 cm 1/Upto10 cm 2/Upto 15cm	3	1	1	2	2
16	Leaf width in (cm):	15	8	5	4	3
17	Petiole length in (cm):	5	4	4	3	1.5
18	Petiole surface: Glabrous 1/Sparselypubescent 2/Villous 3/Stellate-pubescent 4	4	4	4	2	1
19	Pedicle length: 0.5-1 cm 1/1.2-1.5 cm 2	2	1	1	1	2
20	Pedicle surface: Glabrous 1/Sparselypubescent 2/Villous 3/Stellate-pubescent 4/Sparsely Stellate 5	4	4	4	2	5
21	Corolla colour: White 1/White withblack midrib outside 2/Pale mauve-violet 3	1	3	3	1	3
22	Corolla diameter (cm): 0.5 cm 1/1 cm2/1.5 cm 3/2-2.5 cm 4/up to 3.5 cm 5	4	4	4	2	2
23	Corolla sinus: Deep 1/Shallow 2	1	1	2	1	1
24	Corolla surface outside: Glabrous1/Pubescent 2/Stellate-pubescent 3/tomentose 4	4	3	3	3	3
25	Calyx length in (mm)	2-2.5	6-Apr	10-Aug	1.5-2	4-Mar
26	Calyx surface: Glabrous 1/Sparselypubescent to pubescent 2/Stellate-pubescent 3/ Sparsely Stellate 4	2	3	5	2	4
27	Calyx prickly or not: Unprickly 1/Prickly 2;	2	2	2	2	2
28	Calyx sinus: Deep 1/Shallow 2	1	1	2	1	1
29	Anther length in (mm)	6	5	2	2	7
30	Style length: 5-6 mm 1/ 7mm-1cm 2/ upto5cm 3	2	2	8	3	2
31	Style surface: Glabrous 1/Pubescent 2	2	1	2	2	1
32	Peduncle: Branched 1/Unbranched 2	2	1	2	2	2
33	Inflorescence: Subumbellate1/Elongate 2/ supra-axillary 3/ Umbel like Cyme 4	3	1	2	3	3
34	Inflorescence: Leaf-opposed1/Not so 2	2	2	2	2	2
35	Number of flowers per inflorescence:(1 5) 1/(6-10) 2/(10-30) 3	3	1	1	8	8
36	Unripe fruit colour: Green 1/Whitemottled with green veins 2/ Yellow 3	1	2	2	1	1
37	Ripe fruit colour: Yellow -Orange 1/Red 2/Black 3/ Brown4	1	1	1	1	1
38	Fruit diameter (Cm): 0.6-1 cm 1/Upto 1.2 cm 2/2 cm or more 3	1	3	3	1	1
39	Fruit shape: Globose (somewhat spherical) 1/Spherical 2/ Berry 3		1	1	1	1
40	Fruit surface: Glabrous1/Glabrescent 2	1	1	1	1	1
41	Seed Colour : Yellow 1 / Green 2 / to Brown3/ to Black 4/ Purple 5	3	1	1	3	1

Table 4: Morphological Characters and Character States used in the Numerical Analysis.








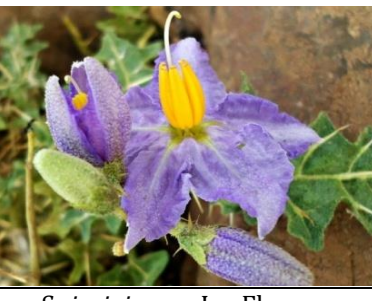
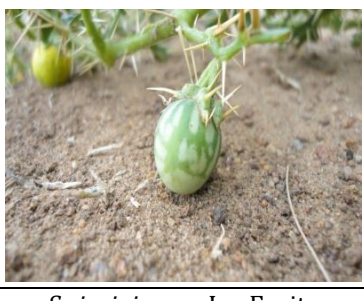



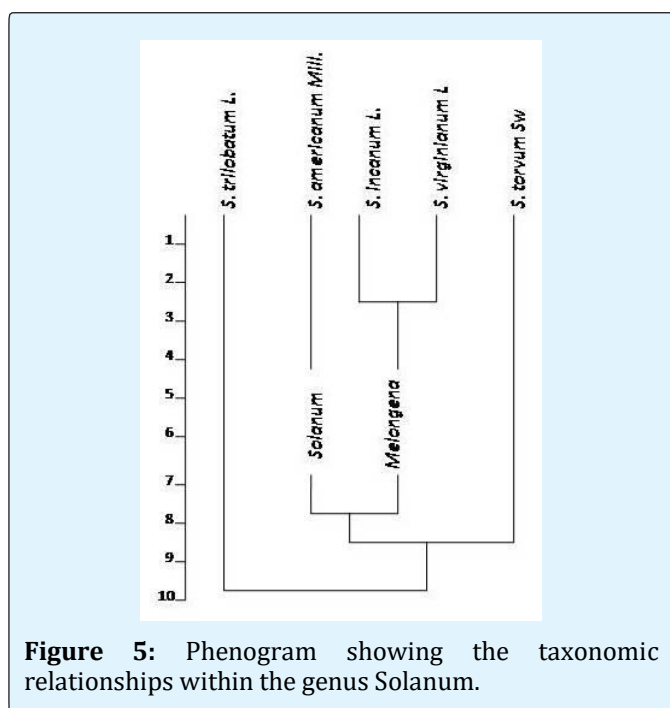
		
<i>S.torvum</i> Sw. -Habit	<i>S.torvum</i> Sw-Flowers	<i>S.torvum</i> Sw-Fruits
		
<i>S.incanum</i> .L - Habit	<i>S.incanum</i> .L - Flowers	<i>S.incanum</i> .L - Fruits
		
<i>S.virginianum</i> L. - Habit	<i>S.virginianum</i> L. - Flowers	<i>S.virginianum</i> L. - Fruits
		
<i>S.americanum</i> .Mill - Habit	<i>S.americanum</i> .Mill - Flowers	<i>S.americanum</i> .Mill - Fruits



Figure 4: Collected *Solanum* species from Southern western Ghats eco-regions.

Results and Discussion

In general, the flowers of *Solanum* are easily identified by their pentamerous and regular flowers with equal stamens that dehisce by terminal pores. The dehiscence of anthers through small apical pores is a hallmark in several species of Solanaceae, especially in the genus *Solanum*. All these classifications based on morphological characters. Some overall recommendations were made for taxonomical rearrangements within the Genus *Solanum*.



Solanum is divided into two large groups based either on oblong or tapered anthers or stellate or non-stellate hairs or presence or absence of prickles by several earlier workers described the giant genus *Solanum* as one of the few species - rich genera of flowering plants [12]. In the

present survey, a total five fresh plant species under single genera of the family Solanaceae have been recorded from Southern Western ghats ecoregions tamil nadu state [13]. In this ecoregions was previously very rich in plant species diversity but due to different development activities and human interfering. Many species either became threatened or extinct from the area. Hence, a detail taxonomic study is essential for knowing the species of the SWG area. Taxonomic study of Solanaceae of the SWGEs area will contribute much toward that study. Taxonomic threatened of the species and their colour photograph will help readers much to identify these plant species. Detail taxonomic analysis for all the species occurring in the SWGEs area has been provided below.

Morphological characters provided essential source for the classification of *Solanum* species. Plant habits, stem structure, leaf; shape, margin, apex and base, petiole pubescence, flower structure and colour, fruit and seed are significantly helpful in the identification of the species [14,15]. Forty-one morphological characters are evaluated and used in the cluster analysis. The resulted phenogram (Figure 5) divided the studied species into two groups; the first contains the species belong to subgenus *Melongena*, the second includes those belong to subgenus *Solanum*. This result is supported the subgenera recognized by some botanists [16,13]. The species belonging to subgenus *Melongena* characterized by the prescence of prominent prickles and stellate hairs, pale mauve-violet flowers arranged in a subumbellate or elongate inflorescence, anthers relatively long and the fruits are yellow-orange or red (Figures 2, 3 and 5). While, the species belonging to subgenus *Solanum* are characterized by lack of prickles and stellate hairs; white flowers and orange or black fruits arranged in a subumbellate pattern and the anthers relatively short. Within the first group, subgenus *Melongena* *S. incanum* delimited early because of the unarmed nature of this species.

Taxa	<i>S.torvum</i>	<i>S.incanum</i>	<i>S. virginianum</i>	<i>S.americanum</i>	<i>S.trilobatum</i>
<i>S.torvum</i>	0				
<i>S.incanum</i>	10.35	0			
<i>S. virginianum</i>	9.82	2.53	0		
<i>S.americanum</i>	4.53	6.72	7.52	0	
<i>S.trilobatum</i>	8.64	7.64	8.12	4.52	0

Table 5: Morphological variations between the studied species based on Squared Euclidean distance.

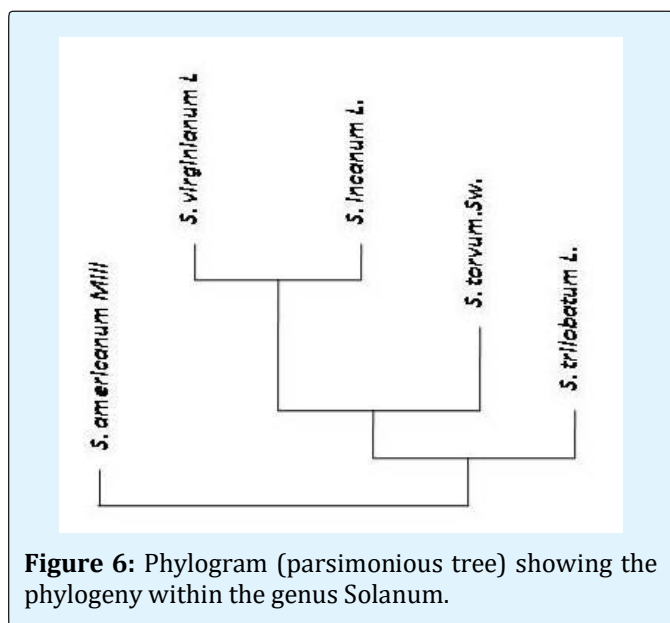


Figure 6: Phylogram (parsimonious tree) showing the phylogeny within the genus Solanum.

Within the second group, subgenus Solanum, *S. americanum* Mill. is separated species. *S. americanum* can easily distinguished by its coriaceous, sparsely pubescent and mostly unequal-paired leaves sub-genus Melongena *S. incanum* highly similar to *S. virginianum* has showed in cluster analysis and has the lowest morphological variation distance 2.53. *S. virginianum* characterized by pale mauve violet petals and *S. incanum* also same petals by white petals with black-violet midrib outside. This finding suggested that *S. incanum* may turn out to be an ecotype of the *S. americanum* or generated from it by adequate hybridization. Natural hybridization is probably more widespread in section Solanum producing morphogenetically complex populations [17]. The phylogram produced from the Parsimony analysis greatly supported the subgenera and sectional arrangement [16]. The Phylogenetic tree showed that *S. americanum* has significant differences of all existing studied species. *Solanum torvum* were great similarity from *S. incanum*, *S. virginianum* and *S. trilobatum*. Moreover it showed the great similarity between *S. incanum* and *S. virginianum* and the close relationship between both of them with *S. incanum* by including them in one clade (Figure 6).

Genera Solanum has lately been studied extensively, taxonomy is still unsettled and debated because of inter and intraspecific hybridization, phenotypic plasticity and polyploidization [18,19]. Our findings suggested that the two species *S. incanum*, and *S. virginianum* can be considered as one species with two subspecies or varieties. Otherwise at least, the two species *S. incanum* and *S. virginianum* should be one species with two subspecies incanum and virginianum.

Conclusion

In conclusion, this study has succeeded in highlighting on number of morphological characters that can be used for taxonomic delimitation of Solanum species; the data attained could be taken along with data from other sources such as molecular taxonomic techniques to enhance proper taxonomic revision of the five species of Solanum [20-26]

Conflict of Interest Statement

We declare that we have no conflict of interest; because of this is the first report in this type of work in Western ghats Ecoregions of tamilnadu.

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